DESIGN OF ILLUMINATION SYSTEM FOR AN OPENCAST MANGANESE MINE

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTERS OF TECHNOLOGY
IN
MINING ENGINEERING

BY

SATYAJEET PARIDA

ROLL NO: 213MN1495

Department of Mining Engineering
National Institute of Technology
Rourkela -769008

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UNDER THE GUIDANCE OF

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2015

CERTIFICATE

This is to certify that the thesis entitled, **“DESIGN OF ILLUMINATION SYSTEM FOR AN OPENCAST MANGANESE MINE”** submitted by SATYAJEET PARIDA (213MN1495) in partial fulfillment of the requirements for the award of Master of Technology degree in Mining Engineering at National Institute of Technology, Rourkela (Deemed University) and is an authentic study analysis work carried out by him under my supervision. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other university/institute for the award of any Degree or Diploma.

Date

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ABSTRACT

The primary objectives of the project was to design an effective lighting layout at different places of work to ensure safe visual working environment in an opencast mining project with keeping in view to meet the statutory standards. The research work was carried out with the objectives to conduct illumination survey and check whether the adequacy of lighting meet the standards set by Directorate General of Mines Safety (DGMS) as well as design of appropriate illumination systems based on illumination requirement for:

- Different places of work in the mine and
- Different Heavy Earth Moving Machineries (HEMMs).

The illumination survey was performed in a mechanized opencast manganese mine project of Manganese Ore India Limited during March, 2015. It included an illumination survey of the existing lighting system in various working areas e.g. haul road, service road, dump yard, dumping road, road to stack yard followed by analysis and improvement measures. The lux meter used for the survey was a Metravi-1332. The existing illuminance levels were found inadequate in the mine dumping yard (at dump edges). The roads though had required level of illuminance but optimization was necessary. The illumination models for various working places in the mine were developed using DIALux software and virtual Philips luminaires were used for the design. DGMS standard for opencast mine lighting was used for both assessment and design of illumination systems. The luminaires used for the design were 250 watts HPSV. For dump yard lighting arrangement model was obtained using 1000 watts HPSV lamps fitted on high mast tower and the design satisfied DGMS standards with a minimum illuminance of 3 lux at the dump edges.

The following recommendations were proposed for consideration to improve the visual level in the work places

- Installation of 250 Watt lamps for the roadways so that the number of poles can be reduced resulting less cost for pole installation and more free areas for movement of vehicles.
- Truck mounted illumination system can be used instead of fixed lighting system at the places which are vulnerable to damage caused by blasting.
- The cabin lighting of HEMMs can be improved by installing proper luminaries.
- High mast lighting tower must be installed in the dump yard to meet the standards at the edges of the dump yard.

ACRONYMS

DGMS	Directorate General of Mines Safety
HPSV	High Pressure Sodium Vapour
HEMM	Heavy Earth Moving Machinery
MOIL	Manganese Ore India Limited
BEML	Bharat Earth Movers Limited
ECSC	European Coal & Steel community
NIOSH	National Institute for Occupational Safety and Health
SIMRAC	Safety in Mines Research Advisory Committee
CEN	ComitéEuropéen de Normalisation
CIE	Commission Internationale de l'éclairage
L&T	Larson and Turbo

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER: 1

INTRODUCTION

1.1. INTRODUCTION

Illumination is a very crucial element of consideration and should be understood thoroughly where the mining activities are nocturnal. Ample amount of Illumination carries undue importance so as to ensure that the working environment is visually viable, in particular in opencast mining field where the additional constraints usually gain an upper hand. Generally, vision is influenced by three main lighting design parameters:-

- Illuminance level of the surface,
- Uniformity of light distribution and
- Glare from sources.

Illuminance levels on visual tasks are taken care by luminous intensity of light sources, whereas uniform distribution pattern of light depends on the technological aspects like luminaire layout, aiming angle and positioning of the light sources.

1.2. MOTIVATION FOR THE PRESENT RESEARCH WORK

In opencast mining, wherein there are mass production requirements therefore activities are also carried out in night shifts ,thereby effective illumination design at workplaces is a priority of top order. Taking into account the safety of miners, the dark surroundings and low surface reflectance may act perilous and adversely affects the productivity. And going by this reason it is become a very onerous task to follow the lighting norms and standards specified by the various regulatory bodies. Hence, a specific scientific approach to the illumination issues in mines must be followed so as to achieve improved standards. A lighting installation is said to be an effective one, when its design and installation is such that an individual may have the trio benefits of working with safety, efficiency, and with reasonable comfort. In the process of lighting design one must begin by carefully determining the needs and then have a detailed overview of crucial frameworks like the practical, technical, and economic factors so as to establish a potent and appropriate illumination system design. The basic motive of lighting design process is to identify the visual needs of miners and indicates in general terms what all means and ends should be followed in the process of accommodating the needs and going long way in overcoming the voids. There are various environmental factors that affect the visibility of the surroundings to name few like low surface reflectance, suspended dust, and water vapors that cause backscattering and thereby reduce apparent luminance. Hence the need of the hour is to have a suitable lighting design which must account for these factors in addition to luminaries design aspects.

1.3. OBJECTIVES OF THE PROJECT

The primary objectives of the project was to design an effective lighting layout at different places of work to ensure safe visual working environment in an opencast manganese mining project keeping in view to meet the statutory standards. The research work was carried out with the following objectives:

❖ To conduct illumination survey and check whether the adequacy of lighting meet the standards set by Directorate General of Mines Safety (DGMS) at:

- Different places of work in the mine,
- Different Heavy Earth Moving Machineries (HEMMs).

❖ To design of an appropriate illumination systems based on illumination requirement for:

    - Haul road
    - Service road and
    - Dump yard.

1.4. LAYOUT OF THESIS

Chapter 1	Introduction to the research work, its importance, goals of the project and Layout of the Thesis.
Chapter 2	Literature Review. Previous research studies on Illumination, basic terminologies of photometry and opencast illumination standards are discussed here.
Chapter 3	Illumination measurement techniques and experimental and design methodology.
Chapter 4	Presents study of illumination survey performed in Dongri Buzurg Opencast Mine, MOIL.
Chapter 5	Contains the results of the illumination survey and brief discussions of the results.
Chapter 6	Presents design model of illumination systems performed in the DIALux software at various workplaces in mine.
Chapter 7	Summarizes major conclusions of the project work

CHAPTER: 2

LITERATURE REVIEW

2.1. INTRODUCTION

Good lighting is very much required for safety and production. Physiological suitability of a person to his working environment is very much important from safety point of view. Certain evidences shows that only 2% are attributed to unforeseen circumstances and 88% of the mine accidents are attributed to unsafe acts. It is realized that if a task is performed in poor lighting for long time sign of strain appear in the individual and if not checked, can lead to physical illness**[2].** The increased mechanization demands that the lighting should be adequate and suitable in order to reduce accidents. Good lighting encourages visual performance, improves quality of work, reduces the frequency of errors and prevents fatigue, and improves visual communication with the working environment. Which results in better production and efficiency.

2.2. BASIC TERMINOLOGIES OF PHOTOMETRY

The different terminologies used in illumination are discussed below:

2.2.1. Luminous Flux

Luminous flux describes the total amount of light emitted by a light source. The amount of light emitted by a light source is the luminous flux Φ and its unit is lumen (lm)**[17].**

2.2.2. Luminous Efficacy

Luminous efficacy is defined as the luminous flux of a lamp in relation to its power consumption and is therefore expressed in lumen per watt (lm/W). Luminous efficacy varies from light source to light source **[17].**

2.2.3. Luminous Intensity

An ideal point-source radiates luminous flux uniformly into the space in all directions. This result partly from the design of the light source and partly on the way light is intentionally directed, therefore, to have a way of presenting the spatial distribution of luminous flux, i.e. the luminous intensity distribution of the light source. The unit for measuring luminous intensity is candela (cd)**[16].**

2.2.4. Illuminance

Illuminance is the amount of luminous flux from a light source falling on a given area and can be determined from the luminous intensity of the light source. Illuminance decreases with the square of the distance from the light source (inverse square law). The unit for measurement is lux**[16].**

2.2.5. Luminance

Luminance is defined as the ratio of luminous intensity of a surface (cd) to the projected area of the surface (m2) **[16].**

2.3. LAWS OF ILLUMINATION

The cosine law and the inverse square law are two very useful lighting laws and discussed below:

2.3.1. Lambert’s Cosine Law

Lambert's cosine law states that the luminous intensity observed from an ideal diffused reflecting surface is directly proportional to the cosine of the angle θ between the observer's line of sight and the surface normal. The representation of Lamberts Cosine Law is illustrated in the Fig. 2.1**[15].**

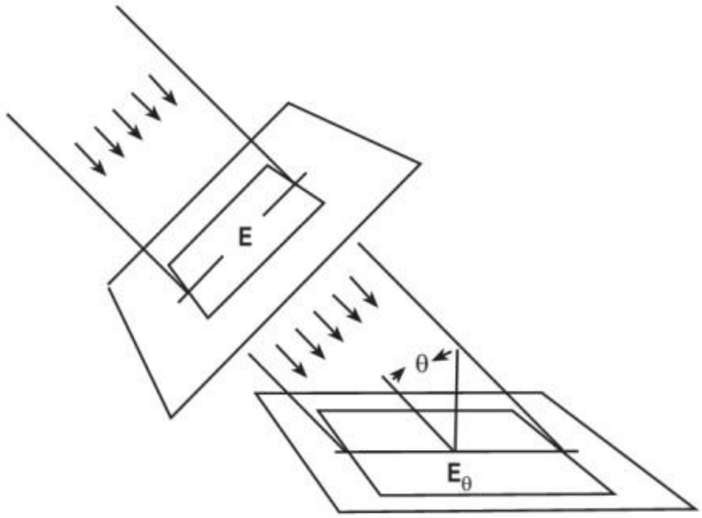

Figure 2.1: Representation of Lambert's Cosine Law [15]

2.3.2. Inverse Square Law

A problem common in lighting system design is determining the illumination on surfaces at various distances from a light source. This can be handled using the inverse square law. The equation relates illumination, intensity, and the distance between the source and light receiving surface is known as the inverse square law, given as:

$$\mathbf{E} = I/D^2 \qquad (1)$$

Where E is illuminance, I is Luminous Intensity and D is the distance between the source and light receiving surface. It enables illumination of a surface to be calculated if the intensity of the light source and the distance between the light source and the surface are known.

The assumption made in the inverse square law is light as a point source. A second assumption inherent in the inverse square law is that the surface area is perpendicular to the direction of light flow. When this is not the case, the inverse square law can be combined with the cosine law given as follows:

$$E = E\text{normal} \times \cos\theta = I \cos\theta / D^2 \qquad (2)$$

Where, cosine of the angle θ is between the observer's line of sight and the surface normal **[15].**

2.4. TYPES OF LIGHTING

The various types of lighting used in opencast mines are presented in the Figure 2.2.

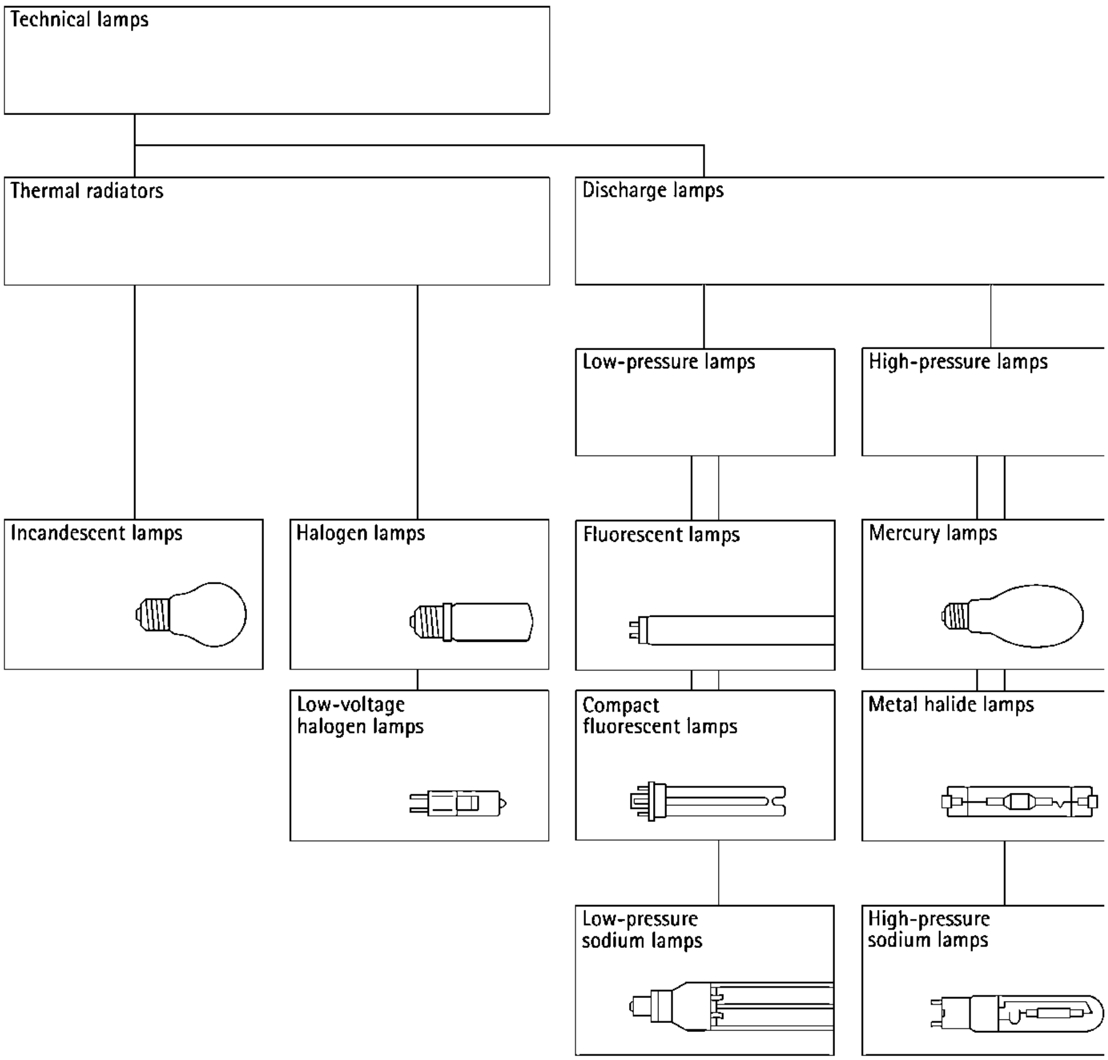

Figure 2.2: Different Types of Lighting Used in Mines [14]

The Table 2.1 summarizes some key criteria for evaluating different sources of lighting.

Table 2.1: Performance of Various Lighting Sources [13]

Type of source	Average rated lifetime (Hrs.)	Lamp efficacy (Lm/W)	Restrike time (Min)	Color appearance	Applications
Incandescent	1000	5-15	prompt	Warm, white to yellow	General Lighting
Tungsten Halogen	2000-4000	12-35	prompt	Warm, white, slight yellow	General Lighting
Fluorescent	10000-16000	50-100	prompt	Warm, white	General Lighting
Mercury Vapor	12000	40-60	3-10	Cool, bluish	Outdoor/Road Lighting
Metal Halide	6000-12000	50-100	10-20	Cool, blue white	Outdoor/Sports Lighting
High-Pressure Sodium Vapor	12000-16000	80-100	0.5-1.0	Warm, golden colour	Outdoor/Road Lighting
Low-Pressure Sodium Vapor	6000	105-160	1-2	Warm, amber	Outdoor/Road Lighting

2.5. MINE ILLUMINATION STANDARDS IN INDIA AND ABROAD

Under the Constitution of India, safety, welfare and health of workers employed in mines are the concern of the Central Government (Entry 55, List-I, Schedule-7, Union, Article 246). The objective is regulated by the Mines Act, 1952 and the Rules and Regulations framed thereunder. These are administered by the Directorate-General of Mines Safety (DGMS). Apart from administering the Mines Act and the subordinate legislation there under, DGMS also administers the Mine Illumination standards and electricity standards. The Table 2.2 illustrates the electrical standards which should be followed in an opencast mine. The minimum standards of lighting recommended for opencast mines in India and various countries in abroad are provided in Table 2.3 and Table 2.4.

Table 2.2: DGMS Electrical Standards [29]

Ground Clearance & Sectional Clearance		
Voltage Class(in KV) (Not Exceeding)	**Ground Clearance (Meters)**	**Sectional Clearance (Meters)**
11	2.75	2.6
33	3.7	2.8
66	4.0	3.0
132	4.6	3.5
220	5.5	4.3
400	8.0	6.5

Maximum stress Factors Of Safety	
Structure	**Minimum Factor Of Safety**
For Metal Supports	1.5
For Mechanically Processed Concrete Supports	2.0
For Hand-moulded Concrete Supports	2.5
For Wood Supports	3.0

Overhead Line Minimum Height	
Line Type	**Minimum Height(Meters)**
For low, medium and high voltages lines up to and including 11,000 volts, if**bare**	4.6
For low, medium and high voltage lines up to and including 11,000 volts, if **insulated**	4.0
For high voltage lines above 11,000 volts **(Bare or Insulated)**	5.2

Table 2.3: DGMS Standard for Opencast Lighting [1]

SL NO.	PLACE/AREA TO BE ILLUMINATED	MANNER IN WHICH IT IS TO BE ILLUMINATED	MINIMUM STANDARD OF ILLUMINATION (LUX)	PLANE LEVEL IN WHICH THE ILLUMINATION IS TO BE PROVIDED
1	General working area as determined by the manager in writing	-	0.2	At the level of surface to be illuminated
2	Work place of heavy machinery	So as to cover the depth and height through which the machine works	5 10	Horizontal Vertical
3	Area where drilling rig works	So as to illuminate the full height of the rig	10	Vertical

4	Area where bulldozer or other tractor mounted machine works	-	10	At the level of crawler tracks
5	Places where manual work is done	To be provided at level of the surface on which work is done	5 10	Horizontal Vertical
6	Place where loading or unloading or transfer ,loading of dumpers ,trucks or train is carried on	-	3	Horizontal
7	Operators cabin of machines or mechanism	To be provided up to a height of 0.8m from floor level	30	Horizontal
8	At hand picking points along conveyor belt	To be provided up to a distance of not less than 1.5m from picker	50	On the surface of conveyor belt
9	Truck hauling roads	To be provided at the level of the road	0.5-3.0	Horizontal
10	Rail haulage track in the pit	To be provided at the level of the rail heads	0.5	Horizontal
11	Roadways and footpaths from bench to bench	-	3.0	Horizontal
12	Permanent paths for use of persons employed	-	1.0	Horizontal

Table 2.4: Mine Illumination Standards in Various Countries (in Lux) [12]

Countries	Shafts	Loading	Haulages	Headings	U/G Offices	U/G Workshop	Face
Australia	20	20	-	20	100	-	-
Belgium	20-50	25	10	20	-	-	-
Canada	21-50	50	21	20	270	270	-
Czech Republic	15	20	5	20	-	-	5
Germany	30-40	40-80	15	40	-	-	-
Hungary	40-100	20-50	2-10	40-60	-	20-50	10
Poland	30-50	10-50	2-10	15-30	-	30-100	2
United Kingdom	70	30	2-5	30	60	50-100	-

European Coal & Steel Community	40-90	-	5-10	15-80	-	-	-
United states	-	-	-	-	-	-	15
South Africa	20-160	10	20	160	-	400	-

2.6. OVERVIEW OF PREVIOUS RESEARCH WORK

A limited number of studies have been undertaken on impacts of poor illumination on safety and productivity of miners. The following segment presents previous research works carried out by different investigators in India and abroad.

2.6.1 Experimental Studies on Mine Illumination Survey

Tripathy and Chowdhury (2014) carried out an experimentalillumination survey of the present scenario of lighting system in various working areas of a mechanized opencast coal mine, the keen observation yielded the results that existing luminance levels were found mostly inadequate in most of the work places and hence, improvement measures were taken by detailed analysis of the prevailing problems and designing a proper framework which fits the required illumination system of that mine by using DIALux software**[11]** .

Pal et al. (2012) proposed design system of haul roads lighting for an opencast coal mine using green energy. A prototype board was also constructed and it showed fairly constant lumen output over varying input voltages **[10]**.

Das and Roul (2005) performed an illumination study at National Aluminium Company LTD (NALCO), a highly mechanized opencast bauxite mine and the proposed design included to provide for 9m lighting tower and 18m telescopic tilt-able tower. Also, design of haul road and auxiliary haul road illumination system was performed**[9]**.

Aruna and Jaralikar (2012) provideda design of a lighting system for both mineral and overburden benches which was based on the minimum acceptable reflected light and the reflected uniformity ratio. In this case a stretch of a 1.0 km long haul road was considered for the process comparison of various types of lighting systems. The design was attempted with five different types of luminaires. Lamp mounting heights were varied at five steps, namely, 8, 10, 12, 14, and 16m. Design under wet conditions incurred an excess cost of 9.4% for mineral bench haul road and 50% for overburden bench haul roads. Design under wet surface conditions ensured the minimum light level even under worst condition of surface reflectivity with marginal increase in cost **[8].**

Karmakar et al. (2005) developed a computer model for design and economic analysis of lighting system in an opencast mine. In this case the study revealed that one major issue in order to achieve all the required lighting standards was mounting heights. With low-wattage high pressure mercury vapor lamps, the pole height was kept lowered to achieve the necessary lighting standards. HPSV lamps possessed better Isolux contour for haul road illumination. For the light sources studied in the work, 100W HPSV lamps at 12m height gave the optimum design (9737 kWh annual energy consumption), whereas at 16m height the minimum energy consumption was 7534 kWh for 150W lamps**[7].**

Mayton (1991) investigated different surface mining operations in various regions of the United States using visual task evaluation, a method used by the CIE and the IES. Here during site visits visibility and illumination data were collected on surface mines and quarries in 15 metal–nonmetal mines and seven coal mines. Visual tasks were identified for equipment operators on 57 types of surface mining and quarry equipment. Visibility and illumination were measured for 159 tasks. Measurements of visibility area were made with the Blackwell model 5 visual task evaluation. Existing illuminance for each task was determined with a Minolta luminance meter and a reflectance standard RS-1. The conclusion was that the illumination level was not constant and varied from mine to mine for the same tasks and equipment and he also suggested that the visibility and illumination on dozers and loaders can be improved if proper aiming of luminaries are assured and by replacing existing low intensity lamps with those of higher intensity**[6].**

CHAPTER: 3

EXPERIMENTAL METHODOLOGY

3.1. INTRODUCTION

For critical and optimized lighting designs mathematical modeling in a computer is required. Based on the positions and mounting heights of the fixtures and their photometric characteristics, the proposed lighting layout can be checked for uniformity and quantity of illumination. For larger projects lighting design software can be used. Advanced programs can include the effect of light from luminaires, allowing further optimization of the operating cost of the lighting installation. Computer modeling of outdoor flood lighting usually proceeds directly from photometric data. The total luminous energy of a lamp is divided into small solid angular regions. Each region is extended to the surface which is to be lit and the area calculated, giving the light power per unit of area. Where multiple lamps are used to illuminate the same area, net contribution is obtained. Again the tabulated light levels (in lux or foot-candles) can be presented as contour lines of constant lighting value, overlaid on the project plan drawing. Hand calculations might only be required at a few points, but computer calculations allow a better estimate of the uniformity and lighting level **[18].**

3.2. ILLUMINATION MEASUREMENTS

Instruments are required to evaluate lighting systems and components. The field of light measurement is called photometry, and the instruments used to measure lighting are called photometers. Many types of photometers are available to measure light energy and related quantities, including illuminance, luminance, luminous intensity, luminous flux, contrast, color and visibility. The photometer is one of the most important tools for illumination measurement and evaluation of efficacy of illumination system.

Specific uses for mine illumination system measurements are:

- Verification of compliance with illumination and luminance specifications in the regulations;
- Evaluation of illumination system design options;
- Checking light distribution;

Photometric measurements in mines are of three types: illuminance measurement, luminance measurement, and reflectance measurements.

3.2.1. Illuminance Measurement

This process measures the incident light (in lux) received by a surface. Most countries specify their lighting standard in lux, so this method is most widely used in mine surveys. Three different techniques can be used in mine illumination surveys:

- Direct planar measurement.
- Separate measurements for direct and diffused light.
- Maximum reading method **[19].**

3.2.2. Luminance Measurement

The photometer is aimed at the surface to be measured. Luminance measurements state that the photometer shall be held approximately perpendicular to the surface being measured. They also require that the sensing element be at a sufficient distance from the surface to allow the light sensing element to receive reflected light from a field not less than $3ft^2$ or more than $5ft^2$**[19].**

3.2.3 Reflectance Measurement

This is the ratio of reflected luminous flux to incident luminous flux. In other words, the ratio of light energy reflected from a surface to the amount striking it. Objects with higher levels of reflectance will appear brighter than those of lower reflectance under the same lighting conditions.

Design of mine illumination requires a thorough knowledge of reflectance of the rock surface in the mine. Four different methods are employed. These are

- Incident–reflected light comparison,
- Standard chips comparison,
- Reflectance standard comparison, and

- Sphere reflectometry **[19].**

For measuring illuminance of different lighting systems and for the purpose of carrying out illuminance survey luxmeter is used. The luxmeter used for carrying out field observations during the working of this project is Metravi 1332 Digital Luxmeter as shown in Figure 3.1.

Figure 3.1 Metravi 1332 Digital Lux-meter used for Illumination Measurements [20]

The different features and specifications of Metravi 1332 lux-meter are:

Features

- CE Approved
- Two unit options- Lux and Foot-Candela
- With PEAK /HOLD data function
- Cosine corrected: f'2 <3%
- Backlight Display

Specifications

i) Display: 3 1/2 digit liquid display (LCD) with maximum reading of 1999

ii) Over range is displayed

iii) Indication for Low battery: A warning is displayed if the battery voltage drops down below the operating level

iv) Measurement Range: 2.5 times per second, nominal

v) Operating Environment: 0°C to 50°C (32°F to 122°F) at < 70% relative humidity

vi) Accuracy: Stated accuracy at 23°C ± 5°C (73°F ± 9°F) < 70% relative humidity

vii) Battery: Standard 9V battery (NEDA 1604, IEC 6F22 006P)

viii) Battery life: 200 hours typical with carbon zinc battery

ix) Dimensions: 190mm (H) x 65.5mm (W) x 35mm (D)

x) Weight: 210g including battery

xi) Photometric Formulas:

10.764 foot candles = lux (lumens/meter2)0.0929.lux = foot candles (lumens / foot2)

xii) Range: 200lux, 2000lux, 20klux, 200klux, 200fc, 2000fc, 20kfc, 200kfc

xii) Resolution: 0.1lux, 0.1fc

xiii) Spectral Response: Metraviphotopic (The Metraviphotopic curve is an international standard for the color response of the average human eye)

xiv) Acceptance Angle: f2 < 3% cosine corrected (150°)

xv) Temperature Coefficient: 0.1x (specified accuracy) / °C (<18°C or > 28°C), 0.056x (specified accuracy) / F° (<64.4°F or 82.4° F)

xvi) Peak hold response time: > 50mS pulse light

3.3. PRINCIPLES OF ILLUMINANCE MEASUREMENT

In mine lighting, illuminance measurements are typically taken for the following purposes:

- To determine the incident luminous energy (lux) on a surface.
- To determine the light output characteristics of a luminaire.
- To determine if illuminance levels are sufficient to qualify the illumination system for DGMS approval.

The illuminance measurement in opencast mines primarily focuses on the following factors:

- **Horizontal Illuminance:** The measure of brightness from a light source, usually measured in foot-candles or lumens, which is taken through a light meter's sensor at a horizontal position on a horizontal surface.
- **Vertical Illuminance:** The measure of brightness from a light source, usually measured in foot-candles or lumens, which is taken through a light meter's sensor at a vertical position on a vertical surface.
- **Uniformity Ratio:** It describes the uniformity of light levels across an area. This may be expressed as a ratio of average to minimum or it may be expressed as a ratio of maximum to minimum level of illumination for a given area.

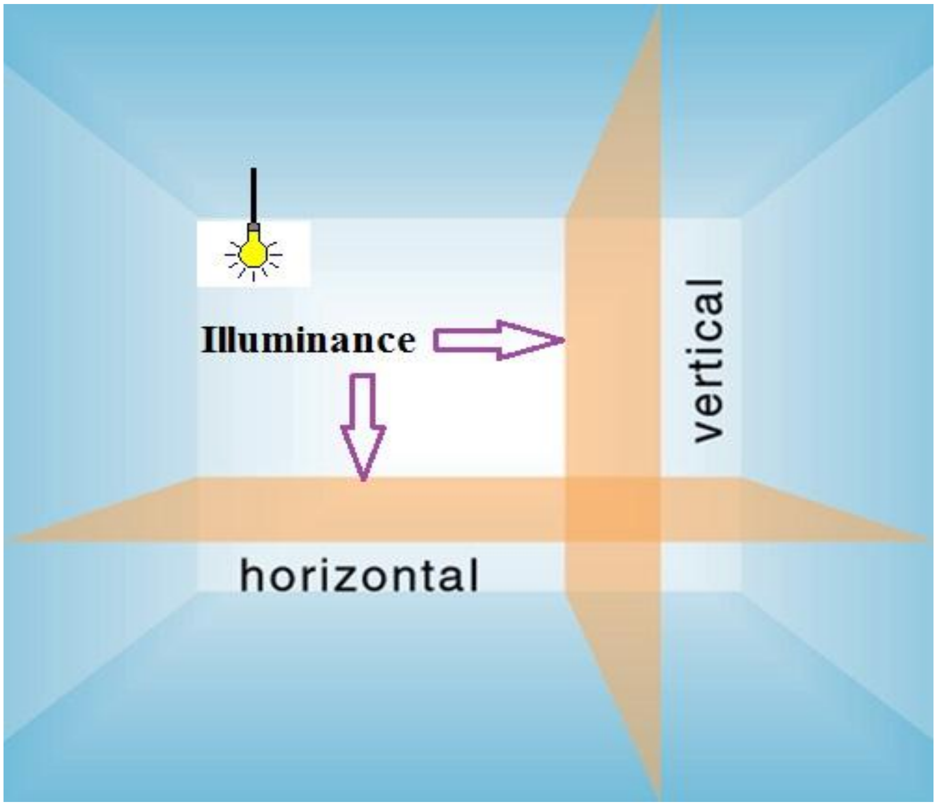

Figure 3.2 Measurement of Horizontal and Vertical Illuminance

3.4. DESIGN OF LIGHTING SYSTEM FOR OPENCAST MINES

Haul roads, Dumping Yards, Moving faces of ore &overburden (OB), within the pit are one of the critical areas in surface mines where lighting installations are not permanent due to regular advancement of the working face. Due to this reason it is very difficult to maintain the lighting standards, as specified by various regulatory bodies. Lighting in mines presents special problems because of the dark surroundings and low surface reflectance. Hence, scientific design of artificial lighting is very important to achieve the minimum required lighting standards. The parameters to be considered for designing suitable lighting system for opencast mines are as follows:

- ✓ Mounting Height
- ✓ Spacing
- ✓ Overhang
- ✓ Inclination [22].

3.5. IMPORTANT PLACES TO BE ILLUMINATED FOR OPENCAST MINES

- At the working faces of ore/overburden to facilitate digging and loading operation for positioning buckets during loading and unloading.
- Material to be loaded and filling level in the bucket or bowl.
- Illumination of haul roads.
- Spotting dumpers for loading and unloading at the dump yard, stack-yards etc.
- Viewing the edge and dump of the general area.
- Inside the cabins of the machineries and along walkways.
- Below the shovels, under the carriage to identify any leakage for handling of trailing cables during relocation maneuvers.
- Over the dock of shovels and draglines for routine maintenance and inspection.
- In case of conveyor haulage system lighting is mainly needed for inspection and maintenance.
- At crusher site, bunkers, vibrators, washers and loading point.
- At maintenance shop, general repairing workshop, auto electrical shop and other places as suggested in DGMS standards **[1].**

3.6. DESIGN METHODOLOGY

The flow chart (Fig. 3.3) depicts the design methodology for the present research investigation.

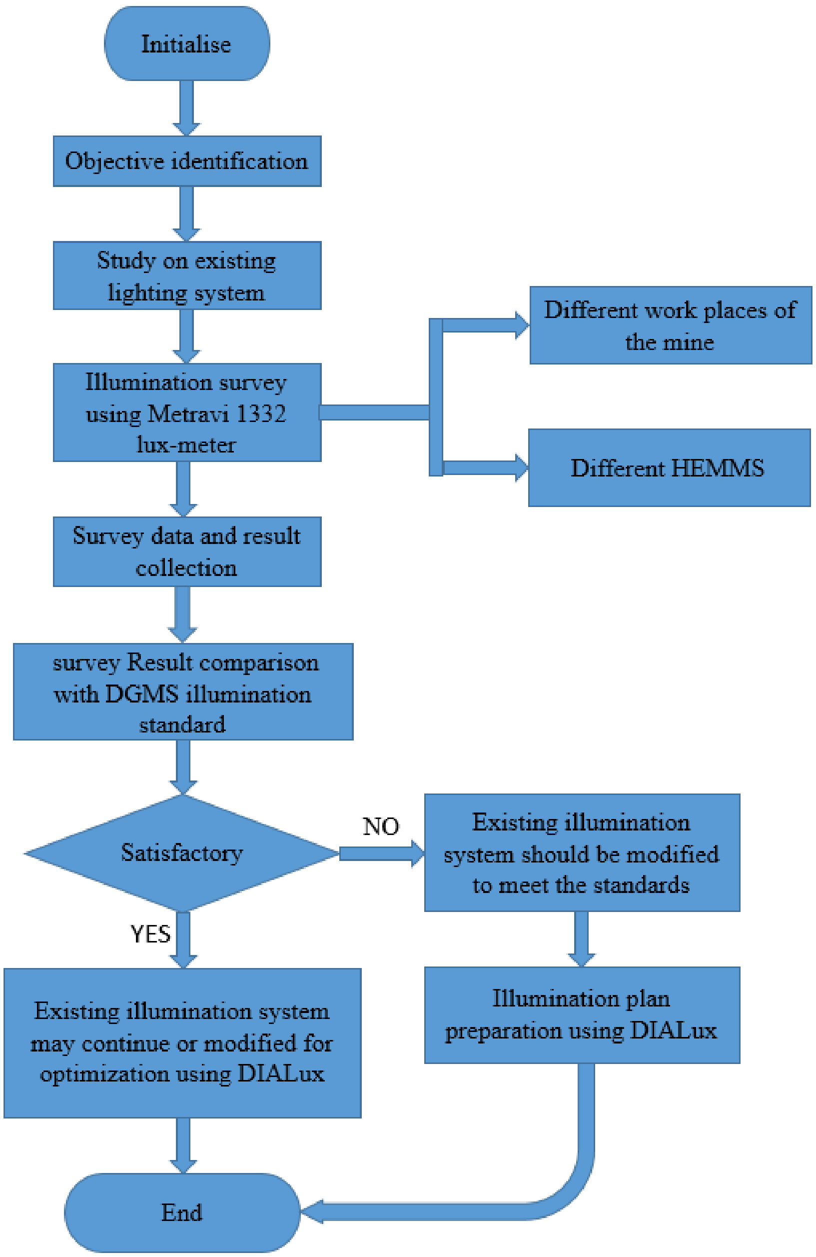

Figure 3.3. Flow chart for Illumination Design Methodology for the Project

CHAPTER: 4

ILLUMINATION SURVEY IN DONGRI BUZURG MINE, MOIL

4.1. MINE LOCATION AND DESCRIPTION

At present, MOIL(Manganese Ore India Limited) operates 10 mines – six located in the Nagpur and Bhandara districts of Maharashtra and four in the Balaghat district of Madhya Pradesh. All these mines are about a century old. Except three, rest of the mines are worked through underground method. The Balaghat mine is the largest mine of the Company which produces one of the best quality manganese ore in the country is also the deepest underground manganese mine in Asia. The mine has now reached a depth of over 500 m from the surface. Dongri Buzurg mine located at latitude 21.17 degree N and longitude 79.65 degree Easting the Bhandara district of Maharashtra is the largest opencast mine that produces manganese dioxide ore used by dry battery industry **[22].**

Fig 4.1 Location of Mine [23]

This ore in the form of manganous oxide is used as micro-nutrient for cattle feed and fertilizers. MOIL fulfills about 70% of the total requirement of dioxide ore in India. The total production of manganese ore from all the mines constitutes about 65% of requirement of the country. At present, the annual production is around 0.9 million tonnes which is expected to grow in the coming years. MOIL has set up ferro manganese plant (10,000 TPY) and Electrolytic Manganese Dioxide (EMD) Plant (1000 TPY) as per its diversification plan for value addition to manganese ore. MOIL is further considering setting up captive power plant, expanding the capacity of ferro-manganese plant and setting up a new Silico Manganese Plant to meet the ever increasing demand of the ferro-alloys globally **[22].**

4.2. GEOLOGY & RESERVES

The in-situ reserves of manganese ore at present, in the leasehold areas of MOIL is around 62.690 million tonnes. The Dongri-Buzurg deposit generally strikes NNE-SSW over a length of 182.8m and dips 50^0—70^0 south. The maximum thickness of the ore body is 26.2m in the central part and the average thickness is 8.5m **[22].** The mine-wise details of in-situ and recoverable reserves of different grades of manganese ore is shown below:

Table 4.1 Manganese Ore Reserves of MOIL [22]

Reserves in Million Tonnes										
Category	**Balaghat**	**Beldongri**	**Chikla**	**Dongri**	**Gumgaon**	**Kandri**	**Munsar**	**Tirodi**	**Ukwa**	**Total**
In-situ	22.832	0.679	5.540	9.902	4.380	1.468	3.963	2.977	10.949	62.690
Recoverable	11.416	0.578	2.543	4.978	2.409	0.809	1.981	1.489	5.474	31.677

MOIL is continuously carrying out exploration for location of new / additional reserves. The main focus area is to prove depth extensions of the ore zone within the existing operating mines. MOIL has a separate exploration wing with its own fleet of equipment. On an average about 2500 m of diamond drilling is done per year which proves about 1.0 million tonnes of additional reserves **[22].**

4.3. LOCATION OF STUDY AREAS FOR ILLUMINATION SURVEY

The study areas of the mine are given below in detail:

4.3.1. Haul Road

Haul roads are generally maintained keeping width three times of the largest plying dumper/trucks. The width here maintained was 10m almost in every places. There were three sections of haul road. Two permanent benches were used as haul road. The service road which connects the mines office to the mine also partially acting as haul road. The service road had intersections connecting to the stock yard and the BDC section. The length of the service road was 840m.

4.3.2. Road to stock yard

The road to stock yard started from the intersection of service road. The width maintained was 10m and the length was 500m. 100Te and 120Te dumpers are used for transporting the ores to the stock yard. Dumpers are maintained properly with special attention to the safety feature.

4.3.3. Dumping Road and Dump Yard

Dumpers are maintained properly with special attention to the safety feature. 100Te and 120Te dumpers are used for dumping of overburden. There is one dumping yard having dimension of 300m*300m. The dumping road was of 10m width and 200m long.

4.3.4. All HEMMs

There were various machineries working to remove overburden, ore face. Survey was conducted on every variety of those.

4.4. OBSERVATIONS OF ILLUMINATION SURVEY

Observations made during the survey are presented below:

4.4.1 Service Road

The service road was of 10m wide and 840m long. The service road were illuminated using 150 W HPSV lamps single row arrangement and hence on the pole side lux levels were much higher and at the end along road width the lux levels were significantly lower, which resulted in non-uniform light distribution. The poles installed are of 11m height and lamps were fixed on opposite horizons. One side is for the road and the other side for the permanent bench haul roads.

4.4.2. Haul Road

The haul road was getting light from the poles installed on the service road. One of the haul road was 40m below the service road and the other was approximately 45m below, so it was just getting the light but not adequate amount. There was no lighting poles at those 2 haul roads the illumination was provided by the lamps fitted on the poles of service road.

4.4.3. Dumping Yard

The dumping yard had an approximate area of 300m x 300m. It had only one mobile lighting tower in function which has 3 numbers of 1000W metal halide lamps in different angles. The tower was operating in the desired part where the operation was being carried out.

4.4.4. Dumping Road

The dumping road was of 200m length. Two mobile lighting towers were installed in gaps for illuminance. The tower had 2 numbers of 400W HPSV lamps fitted on opposite horizons. The first tower was on the right side of the road and the second one at the left side of the road while going from pit to dumping yard.

4.4.5. Road to stock yard

The road to stock yard was of 500m length. It had negligible amount of illuminance because no poles were installed on that road.

CHAPTER: 5

RESULTS

&

DISCUSSION

5.1. INTRODUCTION

The illumination survey was performed in a mechanized opencast manganese mine project (Dungri-Buzurg) of Manganese Ore India Limited during March, 2015. The mine has deposit generally strikes NNE-SSW over a length of 182.8m and dips 50^0—70^0 south. The maximum thickness of the ore body is 26.2m in the central part and the average thickness is 8.5m. The mine has a total in-situ reserve of 9.9 million tonnes from which total recoverable is 4.98 million tonnes[23]. The method of extraction was by pay-loader in combination with tipping trucks and surface miner. The method of overburden removal was by conventional shovel and dumper combination. Ore was transported in to stock yard as well as to nearby BDC section. Haul roads were generally maintained keeping the width 10m.

5.2.RESULTS OF ILLUMINATION SURVEY

The illumination survey readings in various workplaces and HEMMs of the mine are represented in Tables 5.1 to 5.12

Table 5.1: Service Road Illumination Survey Data of Dongri Buzurg OCP

Pole No.	**Spacing (m)**	**Road width (m)**	**Pole height (m)**	**No. of lamps**	**Lamp wattage (W)**	**Illuminance (lux)**				Remarks
						L1	**L2**	**L3**	**L4**	
Mine office to the intersection point										
1	-	10	11	1	400	19.4	10.3	3.4	1.6	
2	41	11	11	1	400	18.2	14.3	2.8	1.9	
3	39	9	11	1	400	16.4	12.8	3.9	1.2	
4	38.8	12	11	1	400	17.3	12.8	2.9	0.9	
5	39	10	11	1	400	14.8	11.2	4.9	1.8	
6	43	10	11	1	400	0.5	0.3	0.1	0	**Defective**
7	47	10	11	1	400	20	9	3.8	1.4	
8	47.5	11	11	1	400*2	26	16.8	9.2	3.2	
9	35	9	11	1	400	21	11.8	6.4	2.1	
10	37	9.8	11	1	400	19.3	13	6.4	2.5	
11	45	11	11	1	400	18.5	11.2	5.2	1.5	

12	47	12	11	1	400	12.4	8.2	3.1	0.8	
13	40.8	10	11	1	400	0.3	0.2	0.1	0.1	**No lamp**
14	39	10	11	1	400	13	5	1.6	0.6	
15	32	9	11	1	400	1.8	1.6	1.4	0.9	**Wrong Lamp position**
16	43	11	11	1	400	20	15.3	11.2	4.6	
17	41	12	11	1	400	17	14.2	10.1	3.8	
18	38	9	11	1	400	12.4	8.3	4.2	2.9	
19	39	10	11	1	400	5.2	7.9	5.4	3.4	
20	42	10	11	1	400	16.8	14.2	9.1	5.3	
21	37	10	11	1	400*2	24.5	18.3	12.4	8.5	
22	43	10	11	1	1000	29.5	18.6	14.2	4.6	

Table 5.2: Haul Road 1(Upper Permanent Bench) Illumination Survey Data of DongriBuzurg OCP

Serial No	Haul Road 1(Upper Permanent Bench)	
	Distance(m) Total Length(480m)	Illuminance at Middle of The Road(lux)
1	-	2.3
2	40	1.8
3	40	2.1
4	40	1.2
5	40	3.2
6	40	3.6
7	40	1.4
8	40	2.7
9	40	2.1
10	40	0.8
11	40	3.9
12	40	5.1

Table 5.3: Haul Road 2(Lower Permanent Bench) Illumination Survey Data of Dongri Buzurg OCP

Serial No	Haul Road 2 (Lower Permanent Bench)	
	Distance (m) Total Length(450m)	Illuminance at Middle of The Road(lux)
1	-	2.1
2	40	1.8
3	40	1.2
4	40	1.4
5	40	1.6
6	40	1.3
7	40	1.4
8	40	1.9
9	40	2.1
10	40	2.3
11	40	2.7
12	10	3.8

Table 5.4: Dumping Road Illumination Survey Data of Dongri Buzurg OCP

Serial No	Distance (m)	Horizontal Illuminance(lux)		
		L1(Left Edge of The Road)	L2(Middle of The Road)	L3(Right Edge of the Road)
1	-	3.8	3.6	4.1
2	20	4.5	4.3	4.9
3	20	8.2	9.8	11.2
4	20	5.1	5	4.9
5	20	3.2	3	2.3
6	20	4.2	3.6	3.4
7	20	4.9	4.1	3.6
8	20	9.2	7.6	5.7
9	20	5.7	4.9	4.3
10	20	3.6	3.4	2.9

Table 5.5: Dump Yard Illumination Survey Data of Dongri Buzurg OCP

Serial No	Distance across The Face of Luminaire (m)	Horizontal Illuminance Across The Face(lux)		
		L1(For lamp1 of 1000 watt)	L2(For lamp2 of 1000 watt)	L3(For lamp3 of 1000 watt)
1	10	7.2	7	6.9
2	20	5.1	4.9	5.4
3	30	3.9	4.1	3.2
4	40	2.6	2.1	2.3
5	50	1.9	1.7	1.6
6	60	1.2	1.1	0.9
7	70	1	0.9	0.7
8	80	0.8	0.7	0.5
9	90	0.7	0.5	0.5
10	100	0.5	0.4	0.3

Table 5.6: Illumination Study of Electric Drill 1

Make	**Sandvik Mining and Construction**	
Model	DI500	
Number of lights	Front-4,Back-2	
Cabin light(lux)	32	
Distance(m)	**Horizontal Illuminance in lux**	**Vertical Illuminance in lux at 2m**
2	4.5	108
4	6.5	80.3
6	10.5	41.2
8	7.1	30.2
10	6.2	20.5

Table 5.7: Illumination Study of Electric Drill 2

Make	Atlas Copco	
Model	CM 470	
Number of lights	Front-3,Back-1	
Cabin light(lux)	16.6	
Distance(m)	**Horizontal Illuminance in lux**	**Vertical Illuminance in lux at 2m**
2	4.2	35.3
4	4.6	27.1
6	5.6	25.4
8	4.3	13.2
10	3.2	6.5

Table 5.8: Illumination Study of Fronthoe Excavator

Make	*Bharat Earth Movers Limited*	
Model	BL9H 4x2	
Number of lights	Front-5,Back-3	
Cabin light(lux)	120	
Distance(m)	**Horizontal Illuminance in lux**	**Vertical Illuminance (at 2m) in lux**
5	105.4	205.3
10	70.3	130.2

Table 5.9: Illumination Study of Backhoe Excavator

Make	*L&T* Construction Equipment Limited	
Model	L&T CK300	
Number of lights	Front-6,Back-3	
Cabin light(lux)	95.3	
Distance(m)	**Horizontal Illuminance in lux**	**Vertical Illuminance (at 2m) in lux**
5	115.3	198.6
10	64.2	117.5

Table 5.10: Illumination Study of Pay Loader

Make	Volvo Construction Limited	
Model	C350F	
Number of lights	Front-5,Back-2	
Cabin light(lux)	48.2	
Distance(m)	**Horizontal Illuminance in lux**	**Vertical Illuminance (at 2m) in lux**
5	20.3	63.2
10	14.5	41.3

Table 5.11: Illumination Study of Dumper

Make	*Bharat Earth Movers Limited*	
Model	BH100	
Number of lights	Front-5,Back-2	
Cabin light(lux)	38.5	
Distance(m)	**Horizontal Illuminance in lux**	**Vertical Illuminance (at 2m) in lux**
5	13.4	20.3
10	8.2	12.2

Table 5.12: Illumination Study of Dozer

Make	*Bharat Earth Movers Limited*	
Model	BD355	
Number of lights	Front-5,Back-2	
Cabin light(lux)	45.6	
Distance(m)	**Horizontal Illuminance in lux**	**Vertical Illuminance (at 2m) in lux**
5	12.5	30.3
10	6.8	19.2

5.3. SUMMARY OF SURVEY RESULTS AND DISCUSSIONS

The survey results that were recorded during the illumination survey are presented in the Table 5.13.

Table 5.13: Summary of Survey Results

Location	Minimum Horizontal Illuminance Standards (DGMS) in Lux	Measured Horizontal Illuminance (Average) in Lux	Remarks
Service Road	0.5-3.0	8.5	Satisfactory
Haul Road 1	0.5-3.0	2.5	Satisfactory
Haul Road 2	0.5-3.0	1.96	Satisfactory
Dumping Road	0.5-3.0	4.96	Satisfactory
Dump Yard	3(Dump Edge)	0.6	Not Satisfactory

To design an appropriate luminaire for the road lighting, prime concern is visibility problems because the surrounding area are dark. The lumen output of the lamp ought to be enough so the road surface has the desired brightness for visibility and even brightness. In general, high pressure sodium discharge lamps are most liked for the road lighting design because they have higher lumen outputs and efficiency compared to other lighting sources. HPSV lamps emit radiation with wavelengths that are less visible to insects and therefore insects are not remarkably attracted to them [24]. Measurement of road illuminance was conducted by creating a virtual grid between two consecutive poles. The horizontal illuminance at each of the points was measured. The road was segregated into four sections along the width as L1, L2, L3, and L4 which represented points at distances of 2.5m, 5m, 7.5m, and 10m, respectively. The illuminance measurement obtained during the survey for service road, haul road1, haul road2 and dumping road satisfied the minimum DGMS lux levels but uniformity of lighting was absent which is a focus point for good road lighting as per the international standard. For the dump yard lux levels were checked at the edge of the yard. As, dump edges need to be seen clearly by the dumper operator hence it is essential to provide adequate illumination to avoid slide/fall accidents. There was no fixed lighting for the dump yard so the illuminance was inadequate[25].

CHAPTER: 6

DESIGN OF

MINE

ILLUMNATION SYSTEMS AT DONGRI BUZURG MINE

6.1. INTRODUCTION

Based on illumination demand in numerous workplaces within the mine appropriate illumination models were developed and conferred during this phase. Throughout the illumination survey, it was detected that the prevailing system of lighting was found inadequate for the mine; hence a replacement system of illumination was developed and projected at acceptable places where illumination levels were inadequate.During this study, the design of lighting systems was performed by DIALux.The illumination level calculations used for the design were supported incorporating virtual Philips luminaires and corresponding lamp flux (lumen) and wattages are given within the design.

6.2. DESIGN OF ILLUMINATION SYSTEMS FOR SERVICE ROAD, HAUL ROAD1, HAUL ROAD2, DUMPING ROAD & ROAD TO STOCK YARD

The road lighting design function within the software consists of a tool that's supported the CIE140/EN 13201 technical report from the European committee for standardization, that helps the user to see the best illumination conditions based on the user information input e.g. vehicle speed, problem of navigation, road traffic, dust conditions, dry/wet condition of the road surface, surface reflectance, surface coating, visibility conditions, etc. The illumination condition obtained for the mine under study was A1 and the illumination category was MEW5**[26].**

The coefficient values used for the planning were obtained using R3 and W3 tables, respectively, for the dry and wet conditions that were integrated within the software. The simulation was performed by optimizing pole distance, height, inclination, and light overhang. As the width of the roads under consideration are equal so a single design is done. A model for road illumination system was simulated which resulted significant improvement in the uniformity ratio and also low wattage of lamp was used than the existing lighting. The optimized parameters for the lighting arrangement are given in the Table 6.1. The lighting arrangement provided on single side of the road, the schematic diagram of the road, is represented below in Figures 6.1 to 6.2. **False color or pseudo-color renderings and gray scale renderings** help in evaluating rendered spaces. These renderings gives a quick idea of the lighting distribution within the space by graduating them on an illuminance or luminance scale and representing them in different colors or gray tones. Grayscale is a range of shades of gray without apparent color. The darkest possible shade is black, which is the total absence of transmitted or reflected light. The lightest possible shade is white, the total transmission or reflection of light at all visible wavelengths. Intermediate shades of gray are represented by equal brightness levels of the three primary colors (red, green and blue) for transmitted light, or equal amounts of the three primary pigments (cyan, magenta and yellow) for reflected light.

Table 6.1: Details of Road Lighting Arrangement Setup

Road Specifications	
Different Road length	840m,500m,480m,450m,200m
Road Width	10m
Luminaire Specifications	
Make	PHILIPS
Model	SGP338 GB 1xSON-T250W SGR CP P-A30
Luminous flux (Luminaire)	21840 lm
Luminous flux (Lamps)	28000 lm
Luminaire Wattage	250Watt HPSV
Maximum luminous intensities at (70°,80°,90°)	457 cd/klm, 165 cd/klm, 44 cd/klm respectively
Luminaire Arrangement	
Arrangement:	Single row, top
Pole Distance	55m
Mounting Height	11.24m
Height	11m
Overhang	1.500 m
Boom Angle	15 °
Boom Length	2.085 m
Minimunm Lux Value	4.43 Lux

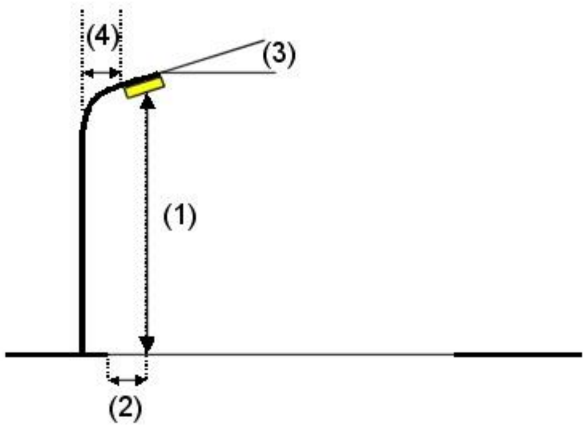

Figure 6.1Lighting Arrangement Provided on single side of the Road. (1) Mounting Height (2) Overhang (3) Boom Angle (4) Boom Length

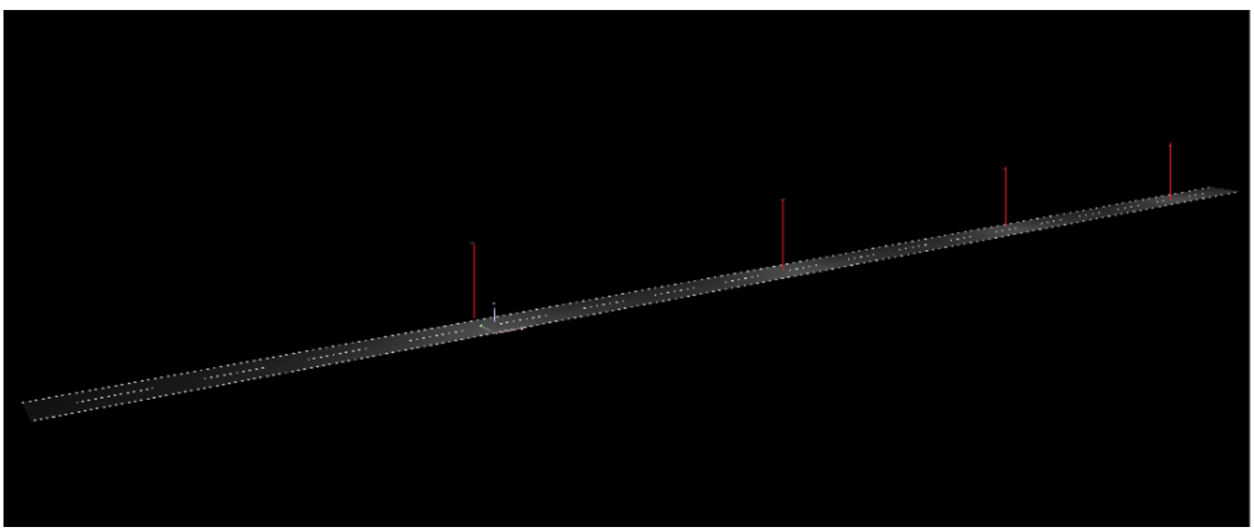

Figure 6.2 Schematic Diagram of the Road

6.3. Design of Dumping Yard Illumination Systems

The illumination design for dumping yards, as per the DGMS guidelines provides visibility of dump edges with a minimum horizontal illuminance level of 3 lux, to avoid slip/fall accidents. For designing point of view it is rather a challenging task to provide the suitable arrangement/positioning of the lighting setup because of the working of dozer crawlers and dumpers in the yard. Hence for arrangement of illumination setup in dumping yards high mast lighting tower which takes minimum of space is used in this case. The Luminaires coordinates shows the position of the pole of the high mast light and the lamp placement angles according to that position. The optimized parameters for the high mast lighting arrangement setup is given in the Table 6.2. The layout and floor plan, exterior 3D view, false color rendering of high mast lighting arrangement as well as the isolines, values of different points, grey scale of different Points of the plan area are represented in Figures 6.3to 6.4.

Table 6.2: Details of Dump Yard High Mast Lighting Setup

Dump Yard Specifications	
Dimension	300mx300m
Luminaire Specifications	
Make	Philips
Model	MVP507 C 1xSON-T1000W WB
Number Of Lamps Used	16
Pole Height	30m
Luminous flux (Luminaire)	107900 lm
Luminous flux (Lamps)	130000 lm
Luminaire Wattage	1000 Watt
Total Luminous flux (Luminaire)	1726400 lm
Total Luminous flux (Lamps)	2080000 lm
Total Luminaire Wattage	16000 Watt
Minimunm Lux Value	4.43 Lux

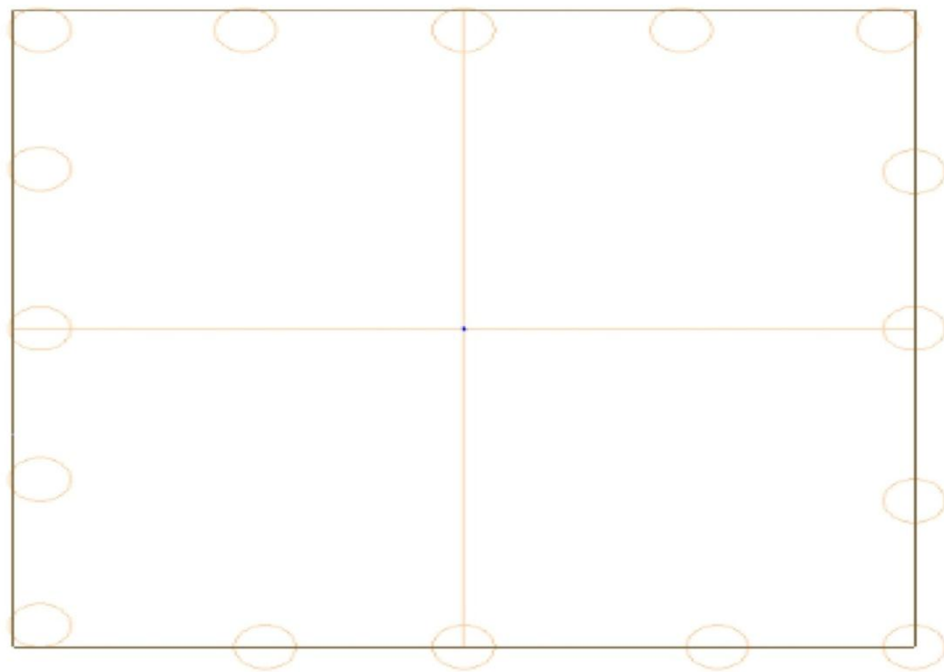

Figure 6.3 Floor Plan of High Mast Lighting Arrangement.

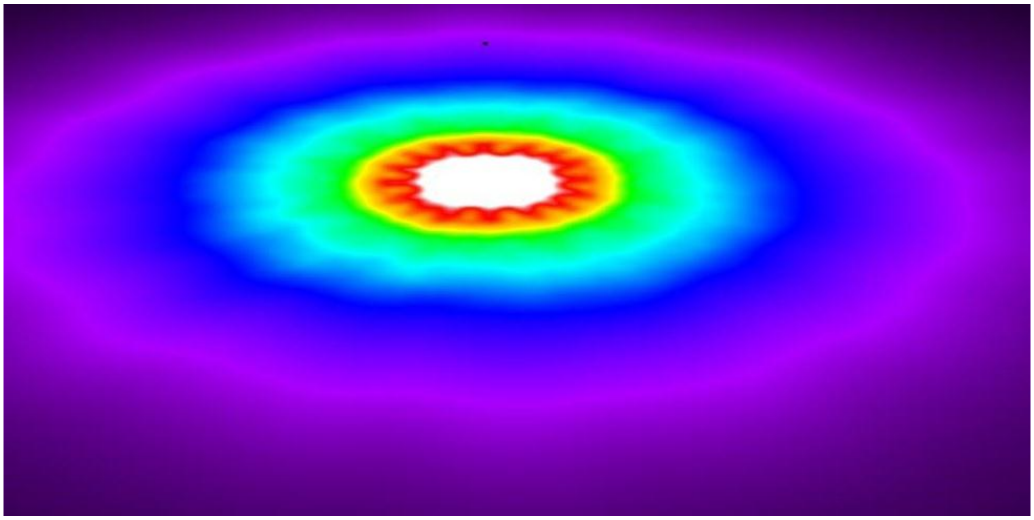

Figure 6.4 False Color Rendering of High Mast Lighting Arrangement

CHAPTER: 7

CONCLUSIONS

&

RECOMMENDATIONS

7.1. CONCLUSIONS

The illumination survey was carried out at Dongri Buzurg Mine, the data collected were analysed and the following conclusions were drawn:

- For service road the average lux levels found was 8.5 lux, whichfulfills the standards set by DGMS i.e. (0.5 to 3.0) lux.
- The haul roads did not have any lighting poles installed. The average lux levels found were 2.5 and 1.96 which falls in the range of DGMS standard.
- The dumping road had an average lux value of 4.96 which was satisfactory but was illuminated by mobile lighting towers due to which there was no uniformity in light distribution.
- The edges of the dumping yard were not properly illuminated. The lux value found was 0.6 which was not satisfactory as per the recommended DGMS standards (3 lux). Design of proper layout has been done which fulfills the DGMS norms.
- The cabin lighting of all HEMMs were fulfilling the DGMS standards (30 lux) except the Atlas Copco CM470 drilling machine, in which the lux level found was 16.6. A 75 -100 W Incandescent lamp or 18-22 W CFL lamp can be installed to provide proper illumination.

7.2. RECOMMENDATIONS

The following recommendations can be considered to improve the visual level in the work places:

- Installation of 250 Watt lamps for the roadways so that the number of poles can be reduced resulting less cost for pole installation and more free areas for movement of vehicles.
- Truck mounted illumination system can be used instead of fixed lighting system at the places which are vulnerable to damage caused by blasting.
- The cabin lighting of HEMMs can be improved by installing A 75 -100 W Incandescent lamp or 18-22 W CFL lamp.
- High mast lighting tower must be installed in the dump yard to meet the standards at the edges of the dump yard.

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